HIGH TEMPERATURE (250 °C) SIC POWER MODULE FOR MILITARY HYBRID ELECTRICAL VEHICLE APPLICATIONS

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Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
26 JUL 2011	**Briefing Charts**	**03-02-2011 to 02-06-2011**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
HIGH TEMPERATURE (250C) SIC POWER MODULE FOR MILITARY HYBRID ELECTRICAL VEHICLE APPLICATIONS	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
R Schupbach; B McPherson,; T McNutt; A Lostetter; John Kajs	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
U.S. Army TARDEC,6501 East Eleven Mile Rd,Warren,Mi,48397-5000	**#22146**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
U.S. Army TARDEC, 6501 East Eleven Mile Rd, Warren, Mi, 48397-5000	**TARDEC**
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)
	#22146

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

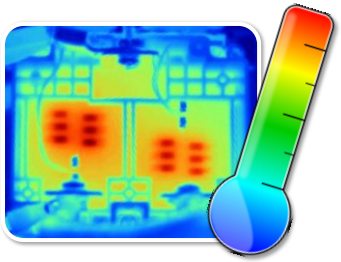
These newly developed high performance SiC power modules can provide substantial system benefits, including Increased efficiency, power density Reduced volume, weight Higher junction temperatures, ambient temperatures

15. SUBJECT TERMS

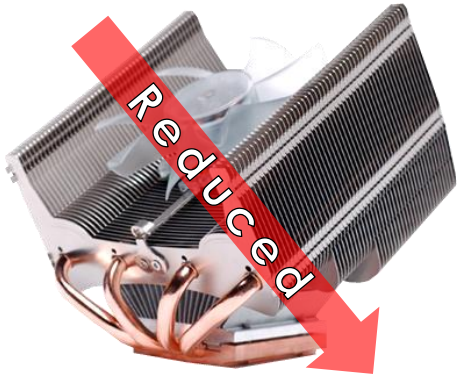
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Public Release**	**23**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Why High Temperature?



What if temperature was *not a limitation*?

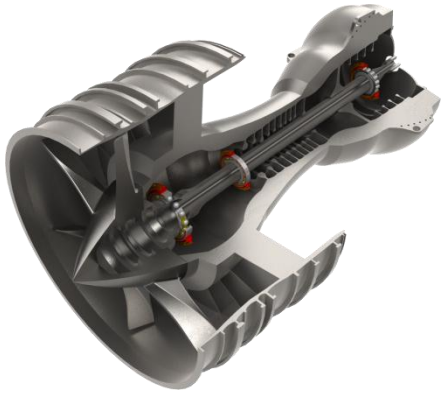


Cooling Systems

Thermal Shielding

- *Efficiency*
- *Power Density*
- *Size & Weight*
- *Complexity*
- *Cost*

Design Tradeoffs

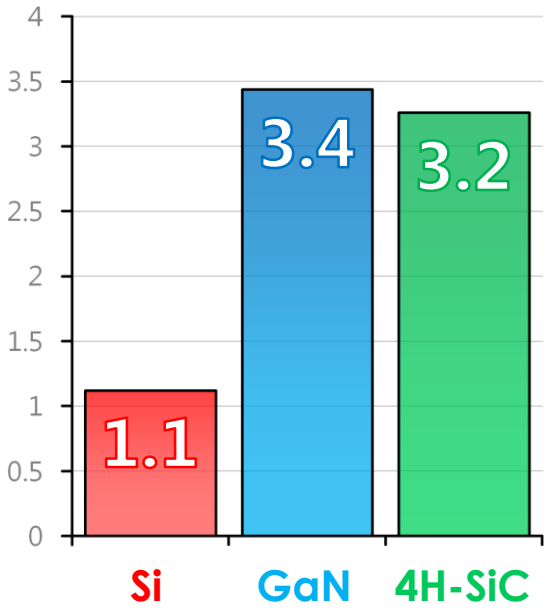


Extreme Environments

Wide Band Gap Semiconductors

POWER AND MOBILITY

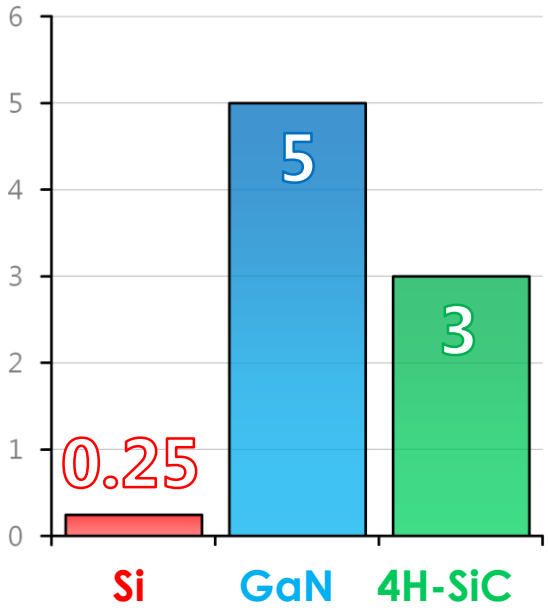
Band Gap
(eV)



larger band gaps mean...

- ***Intrinsic Carriers*** ↓
- ***Operating Temperature*** ↑

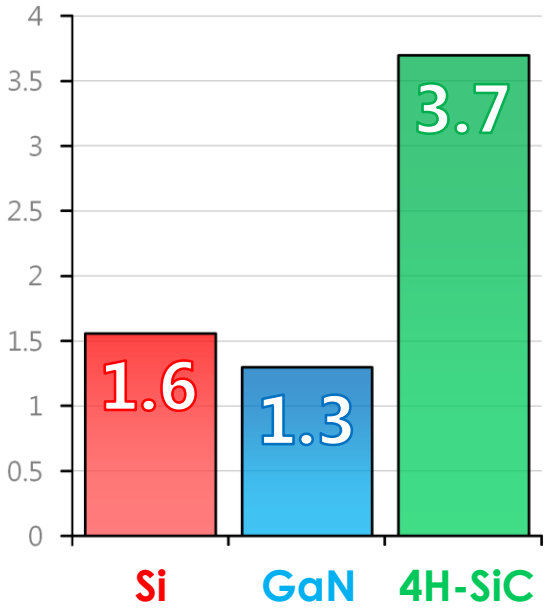
Breakdown Electric Field
($^{MV}/_{cm}$)



higher critical fields result in...

- ***Blocking Voltages*** ↑
- ***On-Resistance*** ↓
- ***Switching Speed*** ↑

Thermal Conductivity
($^{W}/_{cm \bullet K}$)



increased thermal cond. allows...

- ***Heat Dissipation*** ↑
- ***Power Density*** ↑

Applications

POWER AND MOBILITY

Motor Drives

Military
Hybrid / Fully Electric Vehicles

Commercial
Hybrid / Fully Electric Vehicles

Aerospace
More Electric Aircraft

Power Converters

Solar / Wind
Grid-Tie Inverters

Geological
Down Hole Instrumentation

Aerospace
Power Conversion

High Voltage

Industrial
Modernized Power Grid

Commercial
Fault Current Limiter

Military
Advanced Warships

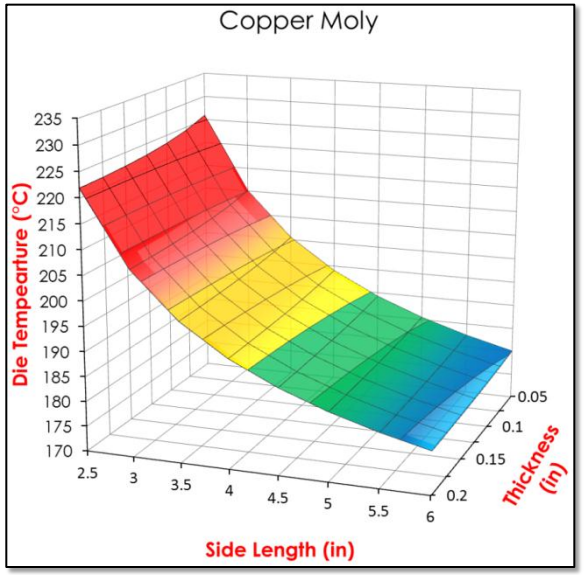
Wireless Telemetry

Industrial
Power Turbine Sensors

Aerospace
Jet Engine / Turbine Sensors

Design

philosophy and processes



Device Neutrality

Use the most suitable device for a given application

JFETs

SemiSouth

Infineon

Microsemi

MOSFETs

CREE

ROHM SEMICONDUCTOR

BJTs

CREE

TranSiC

Diodes

CREE

SemiSouth

Infineon

GeneSiC SEMICONDUCTOR

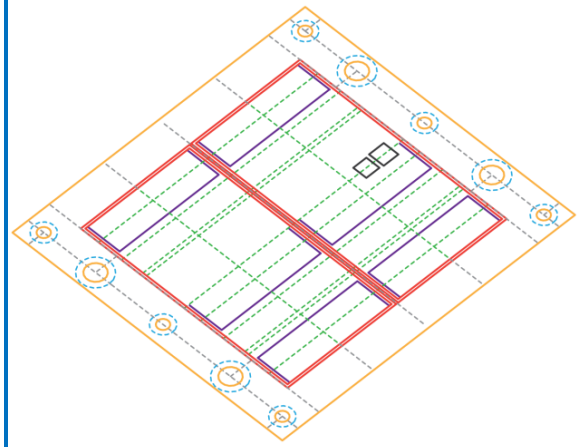
IXYS

Microsemi

ROHM SEMICONDUCTOR

Adaptive CAD Modeling

Technique which allows for rapid configuration of a design with minimal user input



Reference Sketches

Geometry is driven by relationships, equations, and named variables.

Assembly

Components are defined in context and driven by the referenced design variables.

Configurations

Thousands of variations may be rapidly analyzed with this process.

Adaptive Simulation

Using an adaptive CAD model and FEA simulation software, thousands of configurations may be investigated

Base Plate
material
geometry

Power Substrate
ceramic type
ceramic thickness
metal type
metal thickness

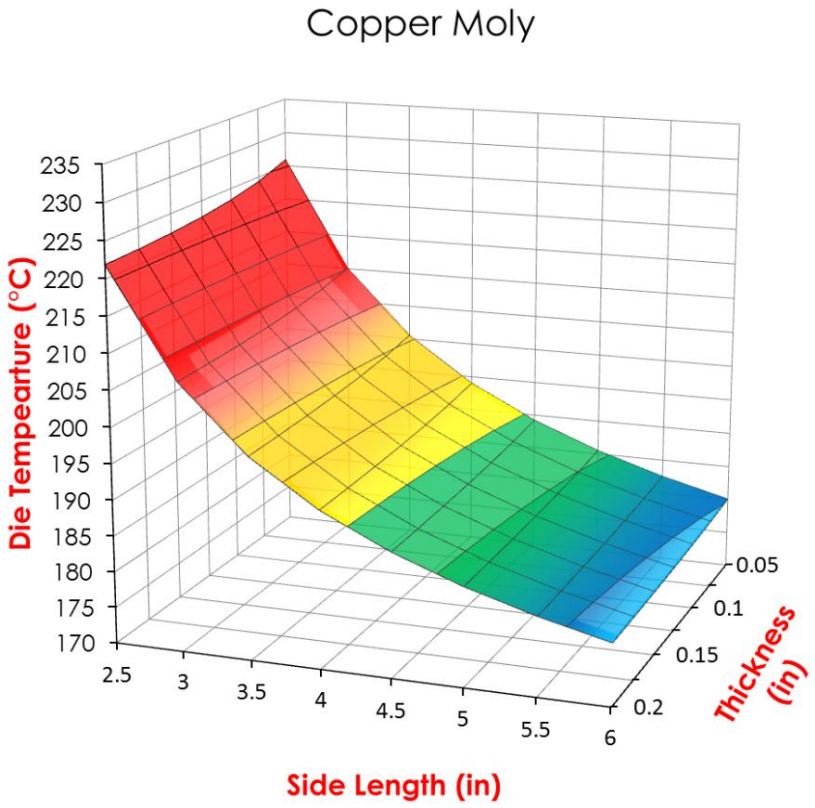
Die Attach
material
thickness

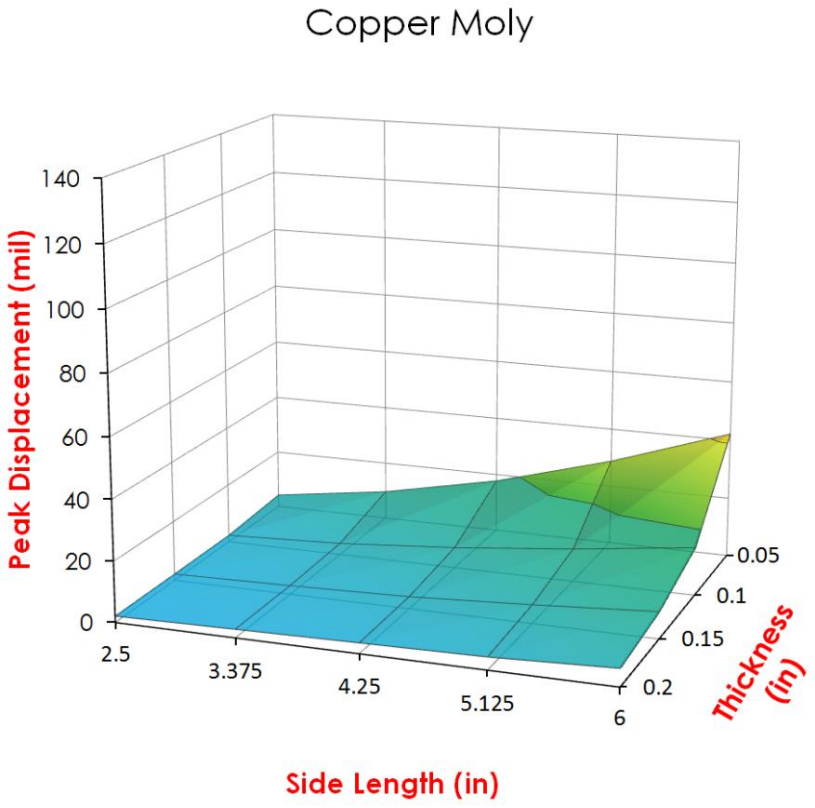
Spacing
die to die
die to edge
substrate to base plate
substrate etch lines
clearances
tolerances

Tradeoffs
thermal performance
stress & displacement
weight vs. performance
volume vs. performance
plastic reinforcements

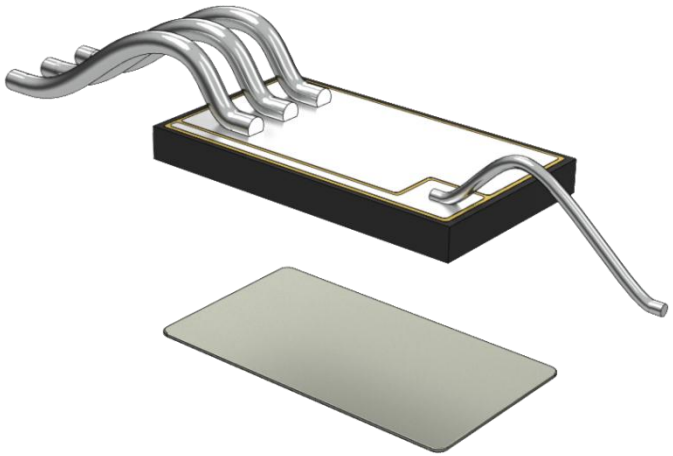
Example Base Plate Analysis

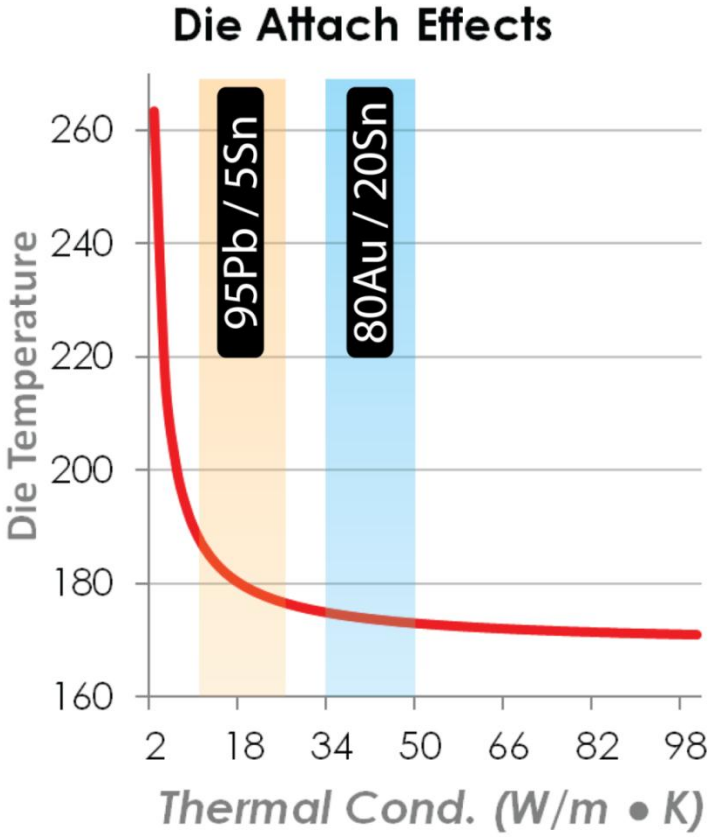
Simulation data is extracted and organized into design surfaces. Tradeoffs are identified and visualized





The thermal conductivity of the die attach exhibits diminishing returns



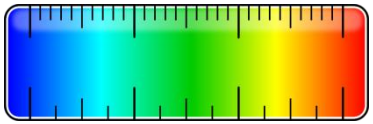


Example Housing Analysis

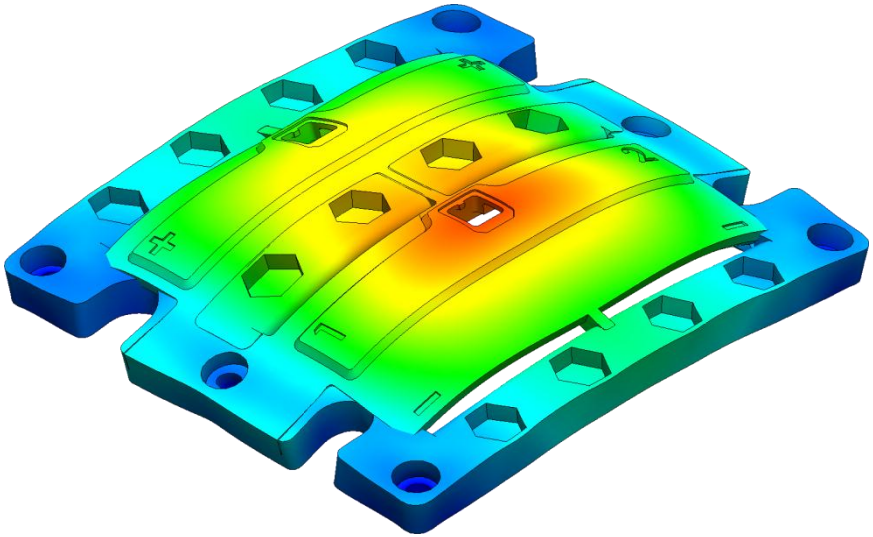
Plastic reinforcing features are carefully designed for minimal stress & displacement

Displacement @ 200°C

0 mil *(0 mm)*

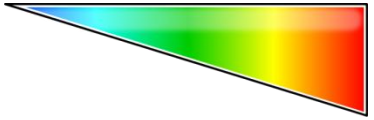


0.9 mil *(0.023 mm)*

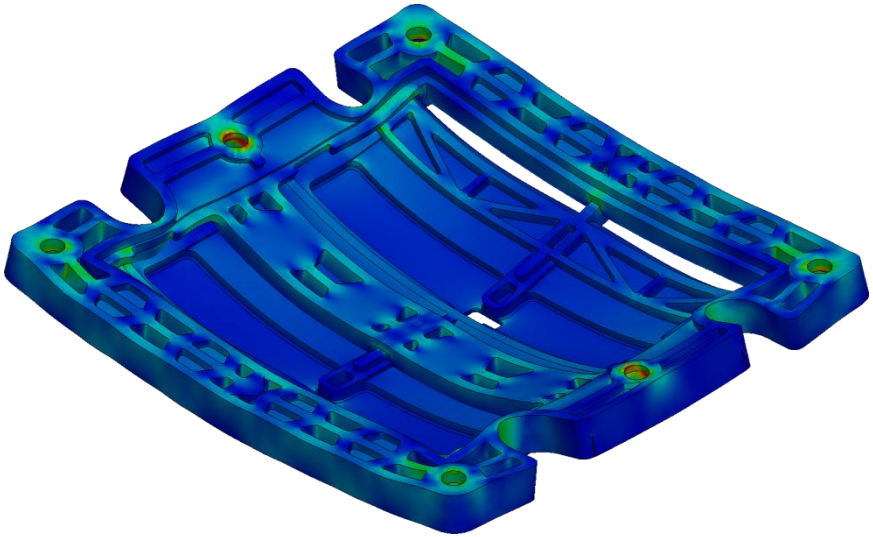


Von Mises Stress @ 200°C

0 MPa

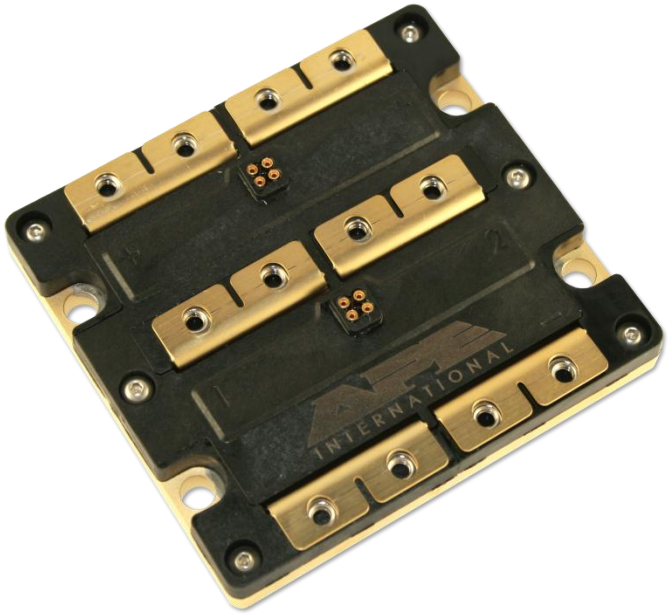


2 MPa

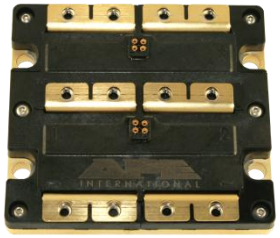


HT-2000

design and features

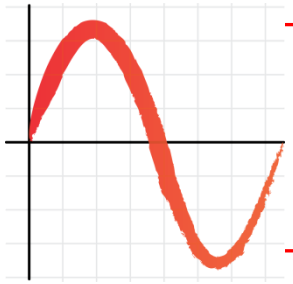


HT-2000 Series



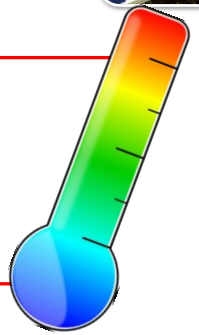
High temperature, high frequency, high power density all SiC half or full-bridge power stage.

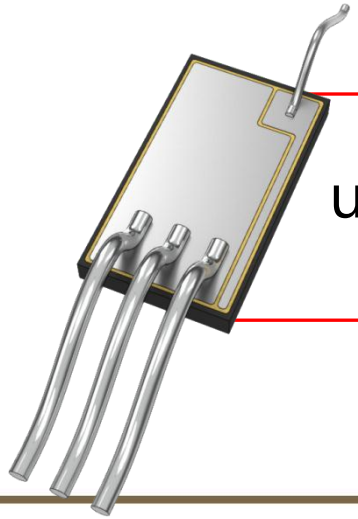


Ratings
1200V
>150A

Temperature
250°C peak
(packaging)





Devices
up to 16 die in parallel
per switch position

** pictured:* ***SemiSouth 50mΩ JFET (SJEC120R050)***

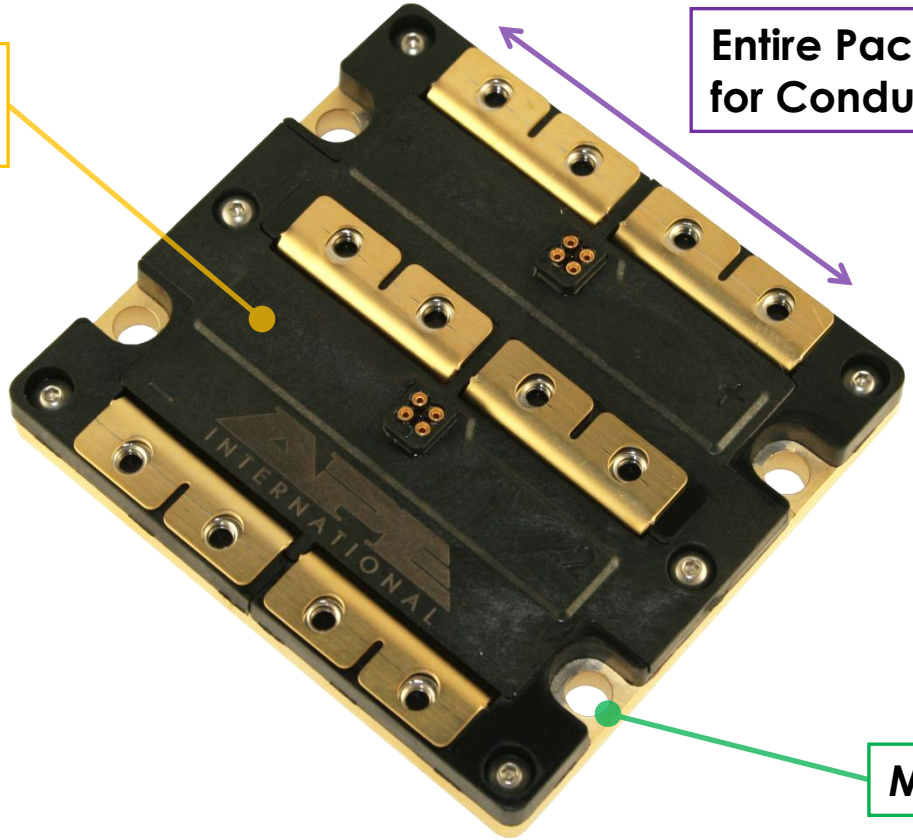
Packaging

Multiple Material Choices Based on Application

High Temp. Plastic Housing

Entire Package Width Used for Conduction

Very Low Profile
0.43 in (10.9 mm)

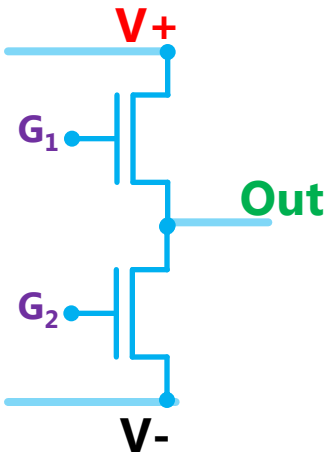


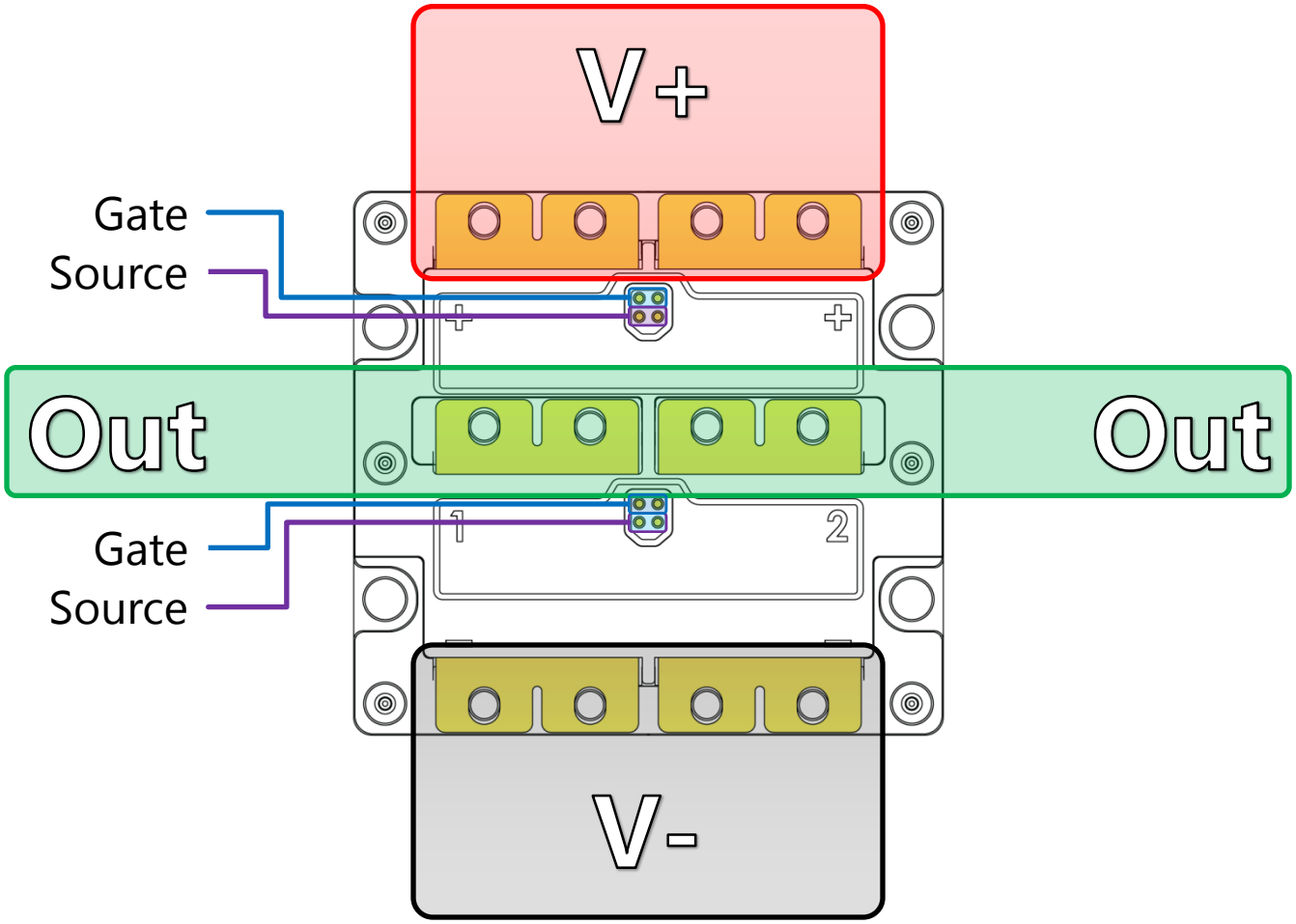
Completely Flux Free Assembly

MMC Base Plate

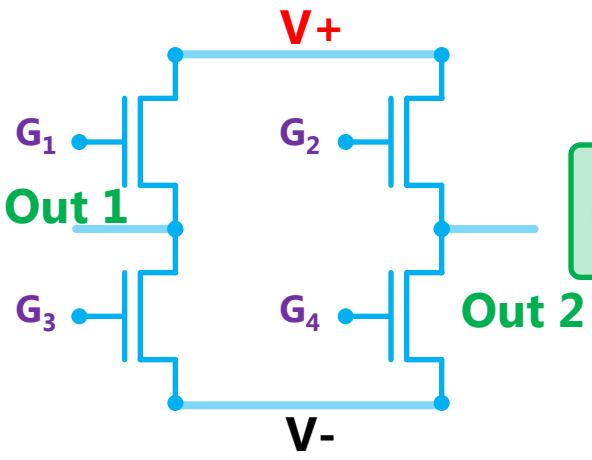
Each module contains four switch positions. Multiple configurations are possible through external bussing

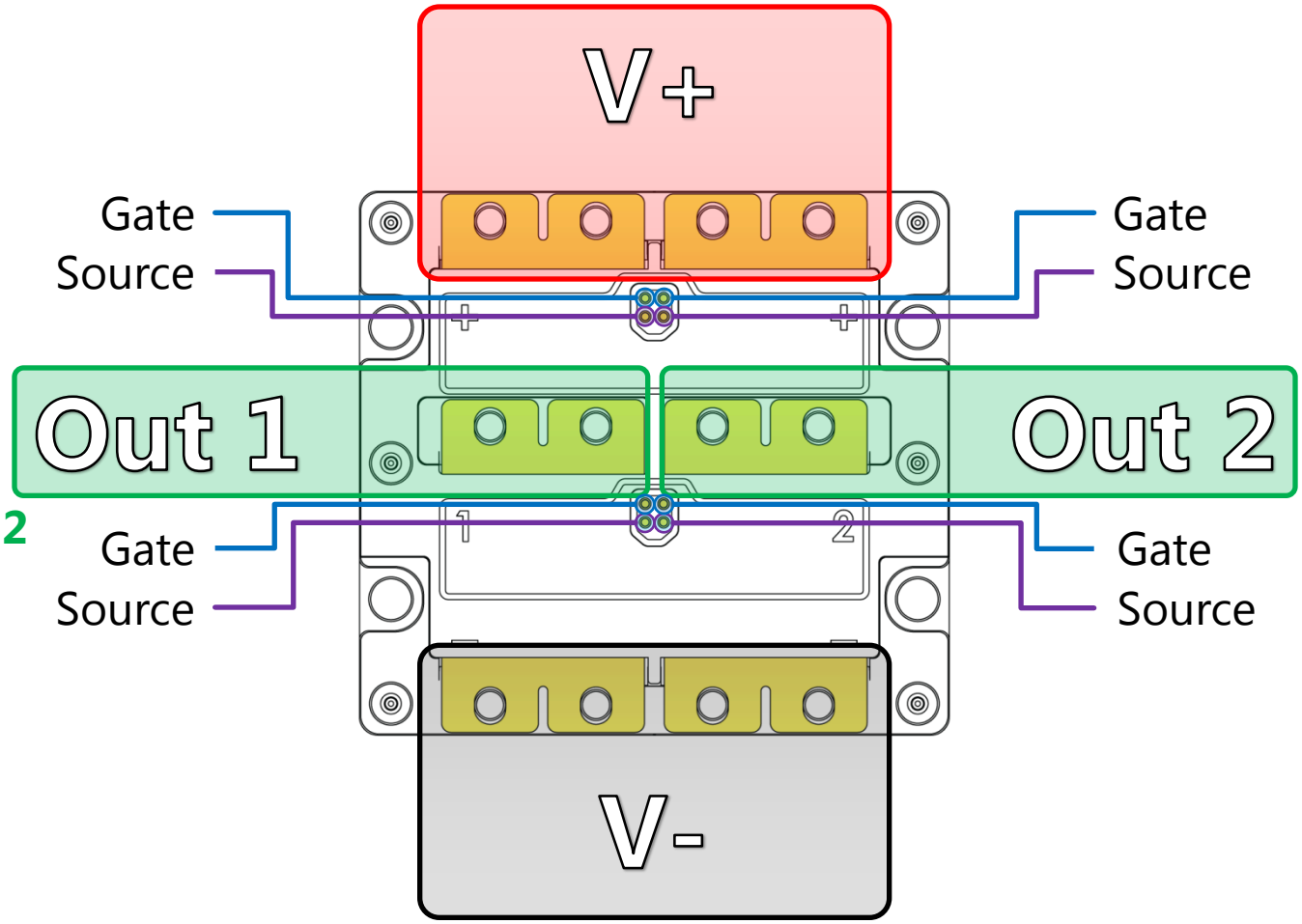
Half Bridge



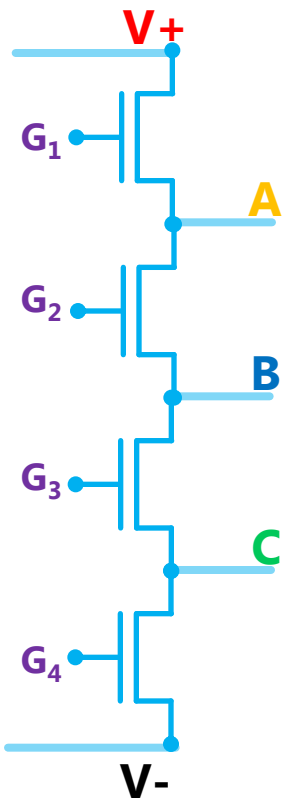


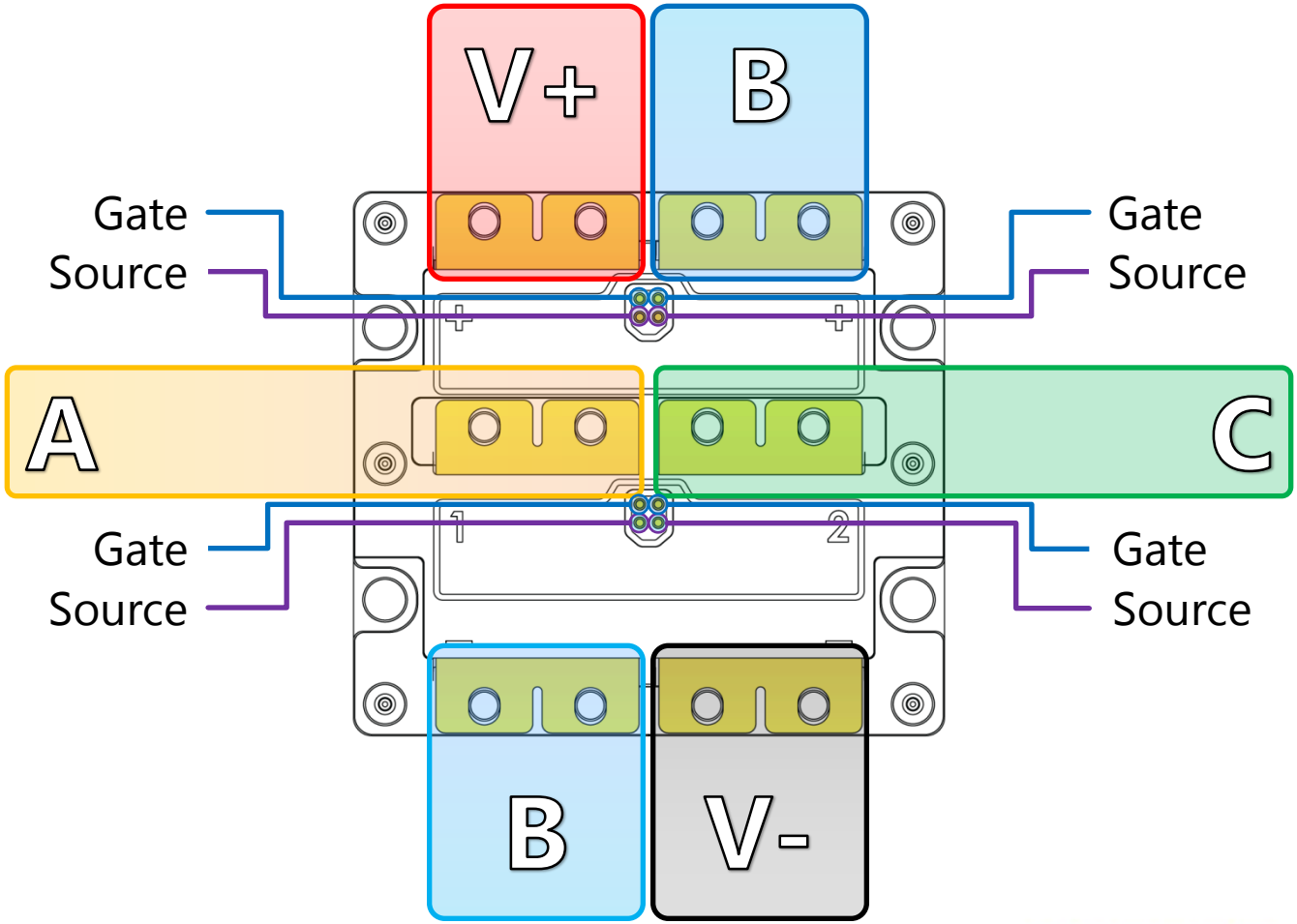
Full Bridge


V+
G1
G2
Out 1
G3
G4
Out 2
V-

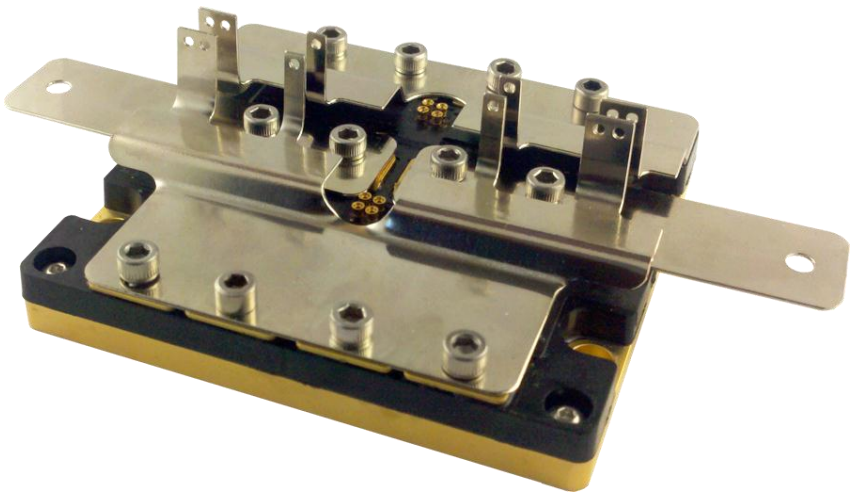

V+
Gate
Source
Gate
Source
Out 1
Out 2
Gate
Source
Gate
Source
V-

Series

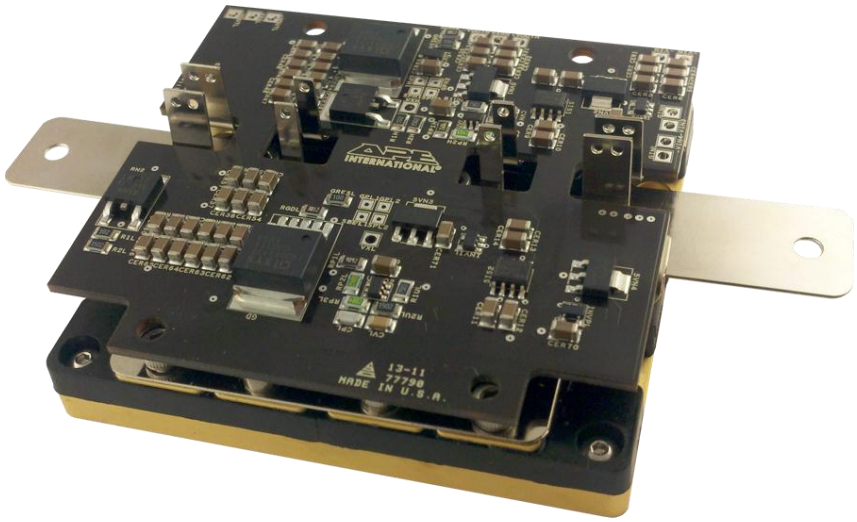

V+
G1
A
G2
B
G3
C
G4
V-


V+
B
Gate
Source
Gate
Source
A
C
Gate
Source
Gate
Source
B
V-

HT-2000 modules are available with custom bussing and gate drives for rapid evaluation



Etched
Copper Bussing

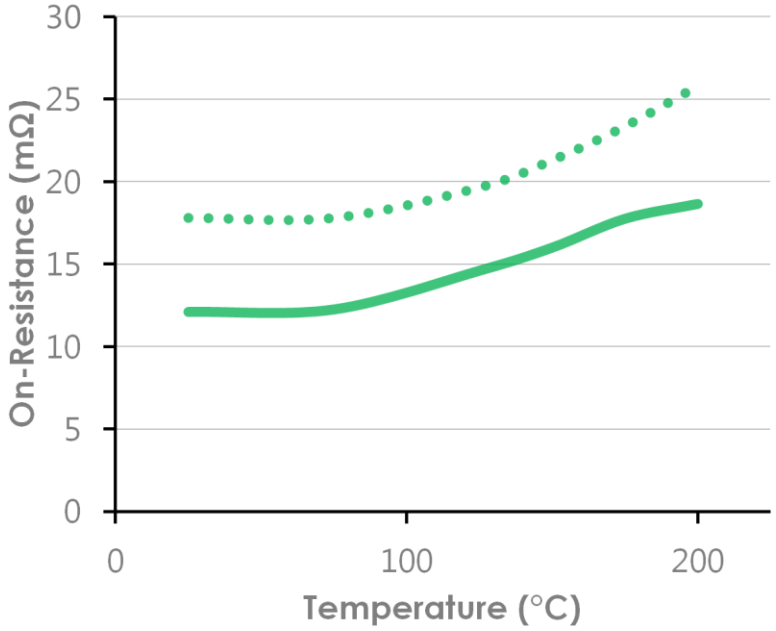


High Frequency
Gate Drive

The paralleled switch positions exhibit very low on state resistances, even at high temperature

MOSFET Configuration

6 MOSFETs per switch position

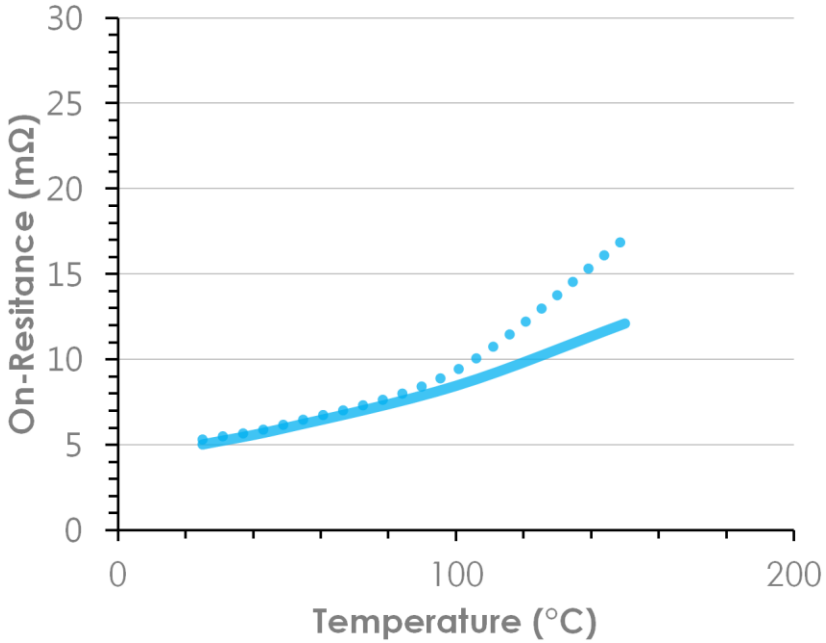


200 A

20 A

JFET Configuration

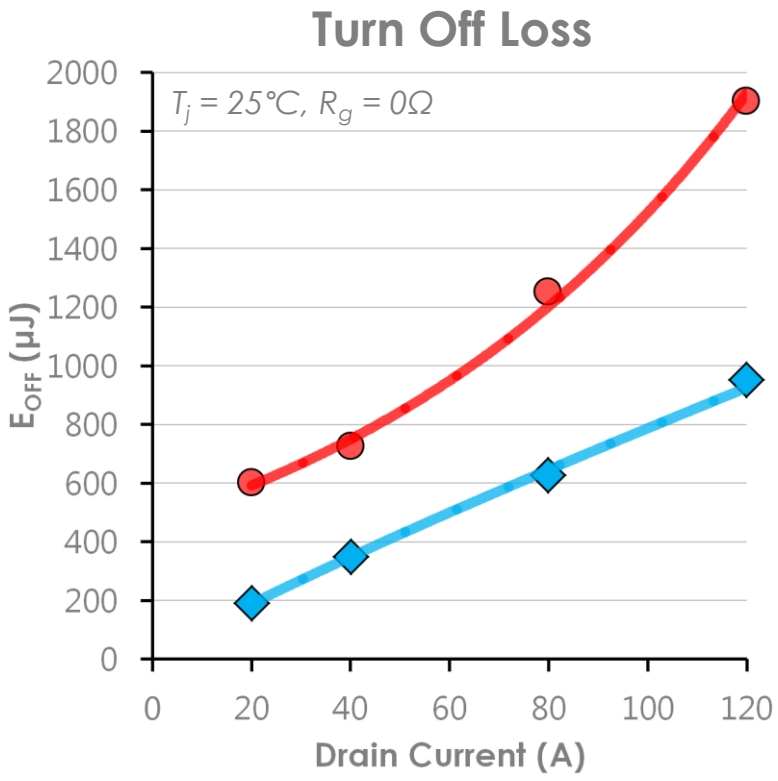
8 JFETs per switch position

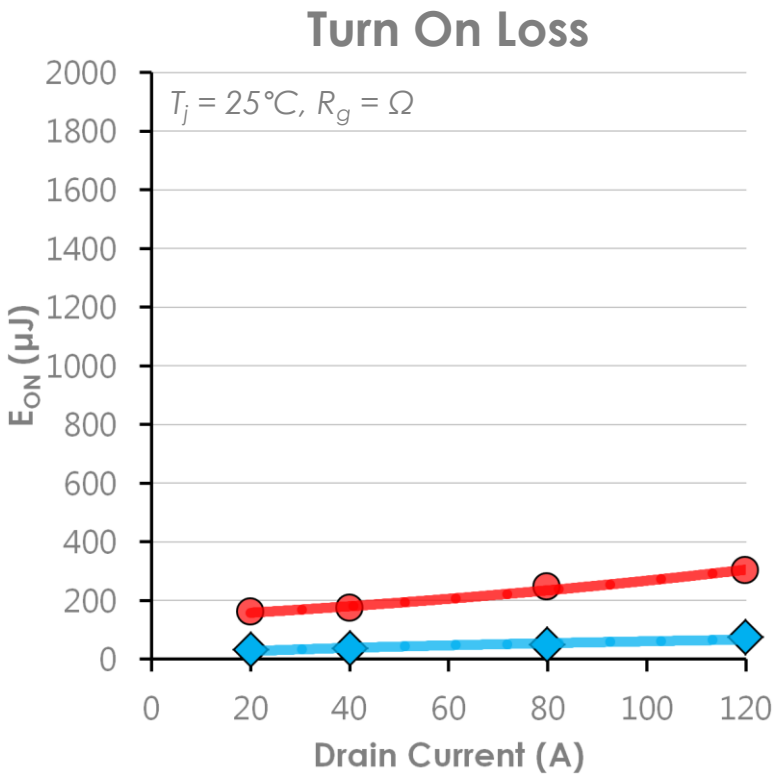


160 A

80 A

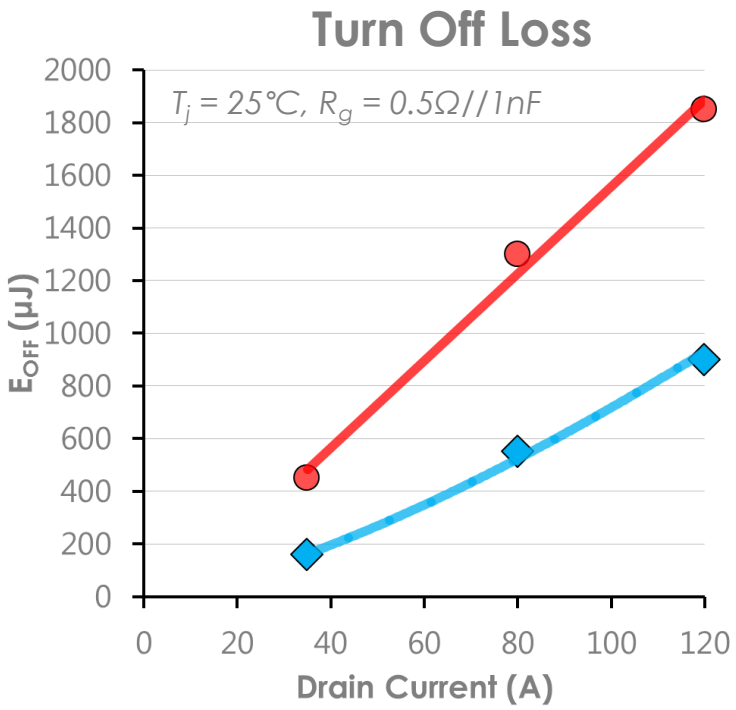
Switching Energy MOSFET Module

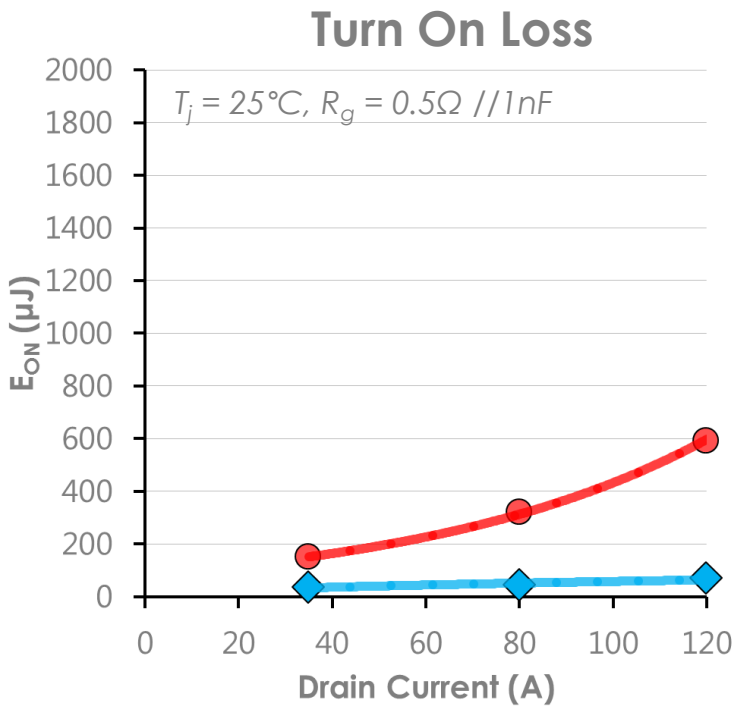




300 V 600 V

Switching Energy JFET Module





300 V 600 V

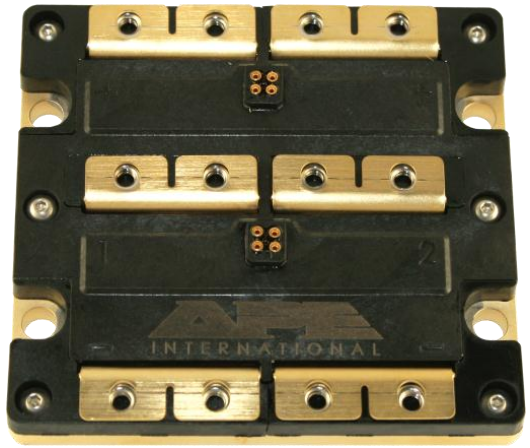
Summary

These newly developed high performance SiC power modules can provide substantial system benefits, including:

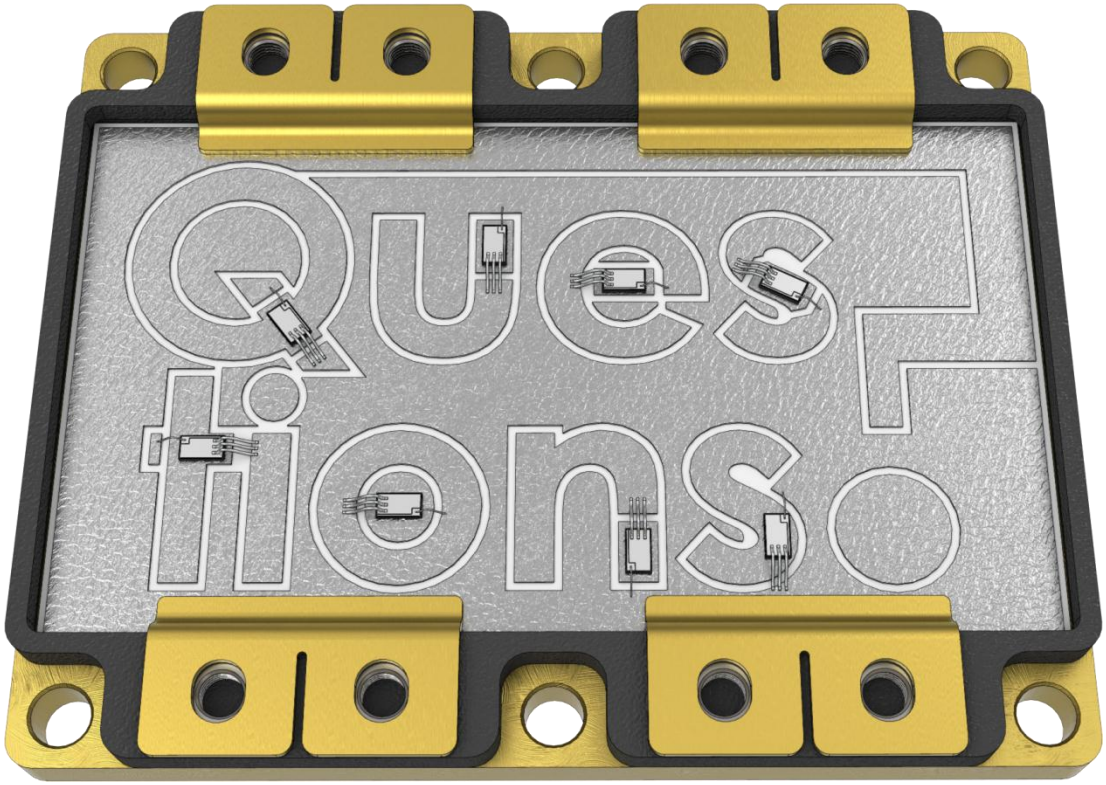
Increased
efficiency
power density

Reduced
volume
weight

Higher
junction temperatures
ambient temperatures



Thank You!



Acknowledgements

This material is based upon work supported by U.S. Army TACOM under Contract Number W56HZV-10-C-0113.